

PROCEEDINGS OF OBSERVATORIES.

The following Reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

The regular meridian observations of the Sun, Moon, major planets, and minor planets down to the $10\frac{1}{2}$ magnitude have been continued as before, during the year 1887. As regards stellar work, the observations for a Ten Year Catalogue, epoch 1880, were completed in 1886; and for the year 1887 a new working catalogue of about 5,000 stars has been prepared, to contain:

- (1) All standard stars, such as are generally included in Greenwich Catalogues, moon-culminating stars from 1887 onwards, close circumpolars, stars near the horizon and zenith, and stars to the 4th magnitude inclusive.
- (2) Stars from Groombridge's Catalogue, and from the Harvard Photometry not in the Nine-year (1872) or Ten-year (1880) Catalogues.
- (3) Additional stars from Piazz's Catalogue, which are being added as occasion offers.
- (4) Miscellaneous stars for special purposes, comet and small planet comparison stars, &c.

Of these 1,800 have been observed during the year, the total number of transits recorded being 5,916, and of meridian zenith distances 5,628.

The mean error in R.A. of Hansen's Lunar Tables with Prof. Newcomb's corrections, as deduced from 106 observations with the transit circle in 1887, is $+0^s.068$; the corresponding quantities for 1883, 1884, 1885 and 1886 being respectively $+0^s.032$, $+0^s.021$, $+0^s.028$ and $+0^s.029$. The five years are consistent in showing an annual period of $0^s.25$ amplitude, with a maximum in September and a long minimum distributed from January to April inclusive. The mean increase in 1887 as compared with the other years is fairly distributed throughout the year.

Five determinations of flexure of the transit circle in 1887

gave results $-0''.15$, $-0''.17$, $-0''.13$, $+0''.12$, and $+0''.02$. The mean from observations in 1886 was $+0''.14$.

The apparent correction to the nadir observation deduced from reflection observations of stars is insensible in 1887, the mean for the year being $+0''.006$. No correction for this discordance has been applied during the year. A new catalogue has been prepared of stars to be observed by reflection, selected with a view to proper distribution in zenith distance, from those observed since 1882, when the new mounting of the collimators rendered it possible to extend such observations to considerable zenith distances. The corrections for R—D as found in the separate years since that time have been remarkably accordant, and the mean has been adopted for use in the Ten-year Catalogue.

A recent investigation shows that the probable error of a single determination of zenith point by the reflection and direct observation of a star is $\pm 0''.43$, and thus on a fine night the probable error of adopted zenith point is about $\pm 0''.20$.

The errors of the new micrometer screws for the microscopes of the transit circle have been carefully investigated, and have been found too small for the advantageous application of corrections. A good deal of attention has been paid to the readings of exterior and interior thermometers in various positions as affecting zenith distance observations, especially those made in the daytime. Further experiments are to be made on this point in 1888 with thermometers suspended at the north and south angles and at the middle of the shutter-opening.

The personal equation machine is now in satisfactory working order, and one series of observations (for the determination of change of personality with varying rate of stellar motion) has been completed, and the results published in the *Monthly Notices*. The machine has been dismantled during the winter, but in the spring an investigation of personality in observing limbs will be undertaken.

Satisfactory progress has been made with the reductions for the Ten-year Catalogue (1877–1886). The first twelve hours of right ascension, containing 1,896 stars, are complete with the exception of the final examination of discordances, and it is hoped to have the whole twenty-four hours reduced very shortly.

Extra-meridional observations of the Moon with the altazimuth have been made as before at every opportunity in the first and last quarters, and occasionally at other times. The instrument has also been used for observations of personality depending upon the direction of motion in the case both of stars and limbs. The results for stars agree well with those already obtained with the personal equation machine, and those for limbs will be available for comparison with future series.

Comet *e* 1886 (Finlay) has been observed on two nights; Comet *b* 1887 (Brooks) on eight nights; Comets *c* 1887

(Barnard), *d* 1887 (Barnard), and *f* 1887 (Olbers) on one night each, and Comet *e* 1887 (Barnard) on three nights. The single observation of Comet Olbers is the outcome of a number of nights' watching, the weather having been uniformly bad in the early morning hours. Twenty-one disappearances and eleven reappearances of stars occulted by the Moon have been observed: in eight cases by two, and in two cases by three observers. These numbers are considerably above the average.

Careful arrangements were made for observing the occultations of stars during the total eclipse of the Moon on January 28, 1888. The observing list sent by Prof. Struve was checked and found to be accurate. Nine telescopes were assigned to different observers, of which four, however, were refractors of only 4-in. aperture. The weather was unfavourable, cloud covering the Moon almost continuously throughout totality, so that the smaller instruments were useless. In glimpses of clear sky the disappearances of six stars and the reappearances of eight were observed with the larger instruments, three of these by three observers and three by two observers. In three cases the disappearance and reappearance of the same star were observed.

Three small devices, suited to the particular circumstances of what promises to be an important class of observations, were found specially useful, and may be worthy of record. In the case of two instruments the eyepiece was mounted excentrically from the axis, at the distance of the Moon's radius, so that, without disturbing the position of the telescope, any point of the limb could be brought into the centre of the field. For setting the position-circles rapidly in the dark, cardboard circles, with notches cut at important points which could be felt and counted with the fingers, were used; and in another case luminous paint was found to work admirably for indicating the figures.

Twenty phenomena of *Jupiter's* satellites have also been observed. Owing to the unfavourable position of the planet, this number is smaller than usual.

A large amount of experimental work has been done during the past year in connection with stellar photography. Arrangements were completed in February for taking photographs with the Lassell reflector; and besides small preliminary plates, several circular plates of $8\frac{1}{4}$ inches diameter were exposed. The results seemed to show that—

1. The mounting allowed of too much shake in the telescope, resulting both from slight wind and from the small motions required at times to correct defective clock-driving.

2. The reflective power of the mirror surface is now somewhat low, so that very long exposures are necessary.

On the return of the Astronomer Royal from the International Photographic Conference at Paris, where he had undertaken to make experiments as to the possibility of using curved plates, one of the 4-in. photoheliograph object-glasses, by Dall-

meyer, used in the Transit of *Venus* (1874) Expedition, was mounted on the Sheepshanks' Equatorial with a view to carrying out these experiments. Preliminary photographs on flat plates for the determination of focus gave unexpectedly good results, especially as regards extent of field, the star images being sensibly circular to nearly 2° from the centre of the field. Accordingly some mechanical improvements having been made in the instrument, two long series of photographs of the *Pleiades* with different exposures, and in different parts of flat and curved plates respectively, have been obtained. The total number of plates taken is as follows:—

8 plates 5 in. \times 4 in.; flat.
 17 „ 6 in. \times 6 in.; „
 13 „ 6 in. \times 6 in.; curved.

the total number of exposures being 128, varying from a fraction of a second to an hour. Comparison of the results indicates that the advantages of using curved plates are doubtful, while micrometric measures made on the flat plates show that for some distance beyond the limit where the star images are sensibly circular, their relative places can still be measured with the accuracy of meridian observations, and with no sensible systematic error depending upon magnitude or time of exposure.

As an experiment on the adaptation of an ordinary refractor to photography, a corrector consisting of a concave crown and convex flint lens was constructed to be placed about 30 inches within the focus of the South-East Equatorial, the effect being to bring the rays F and H to the same focus without alteration of the focal length for the former ray. The field available with this combination is very small, but some satisfactory photographs of *Jupiter* and *Saturn* and of close double stars were obtained, a Dallmeyer doublet (“rapid rectilinear”) being used in most cases to enlarge the image about eight times before it was received on the photographic plate.

The regular observations with the spectroscope for the determination of the motions of stars in the line of sight have been intermitted twice during the past year, viz. from February 16 to the end of June, when the South-East Equatorial was in use for photography, and from the middle of November to the end of the year, when attention was paid to the spectra of γ *Cassiopeiae*, β *Lyrae*, and several stars of *Secchi's* third type in compliance with a request from Mr. Lockyer. The results for motion in the line of sight are thus not so numerous as usual; in all 368 measures of displacement of either the F or b lines have been obtained from the spectra of 44 stars, besides 6 measures of the displacement of the F line in the spectrum of the great nebula in *Orion*, and 45 measures of lines in the spectrum of the Moon or sky, as a check on the adjustment of the instrument and general accuracy of the measures. The observations of stars

with bright lines or fluted spectrum are still in progress, γ *Cassiopeiae*, β *Lyræ*, *Mira Ceti*, β *Pegasi*, and α *Orionis* having been examined.

With the photoheliograph, photographs of the Sun have been taken on 213 days, and 432 selected for preservation. The additional photographs obtained from India and Mauritius leave only six days in the year ending 1887, October 31 on which no photograph is as yet available for measurement. The decrease in spotted area has continued throughout 1887, though there was a partial recovery at the beginning of the year from the marked period of quiescence in the autumn of 1886.

The chronometer work has been very heavy during 1887. In addition to the ordinary issues for repair and testing on return from service, a series of competitive trials of chronometers and deck watches has lasted continuously throughout the year, with the exception only of two periods of a fortnight each.

Arrangements for enlarging the computing-rooms, and adding a third story with 18 feet dome, were completed in the autumn, and operations were commenced in November. It is proposed to transfer the photoheliograph, which has hitherto been placed in a temporary wooden hut, to the new dome; and if, as is hoped, a new photographic equatorial is eventually obtained, that instrument will be mounted there, the photoheliograph tube being carried on the same mounting.

An equatorial, by T. Cooke & Sons, has been mounted in the south ground for observation of occasional phenomena.

The volume of *Greenwich Observations* for 1885 was distributed last October, and the printing of that for 1886 is well advanced. The reduction of the observations of all kinds is in a forward state.

It may be mentioned that the Astronomer Royal attended the Conference at Paris on Stellar Photography. Mr. Turner, aided by a grant from the Royal Society, went to Russia to observe the Total Solar Eclipse of 1887, August 19.

Royal Observatory, Edinburgh.

During the above year star observations for time have been continued as usual. The daily time-signals by electric time-ball on Nelson Monument, electric time-gun at the Castle, and electric control of many public clocks, partly direct and partly at second-hand—through the trusty medium of Messrs. Ritchie & Sons, clock-makers in Edinburgh and Leith—have also been given as usual.

The bi-diurnal observations at fifty-five stations of the Scottish Meteorological Society have been computed at the Observatory for the purposes of the Registrar-General of Births, Deaths,

&c., and have been printed immediately and successively in that officer's monthly and quarterly returns.

The MSS. with plates (to the number of 221) of a new volume—chiefly spectroscopic—of the *Edinburgh Observatory Series*, to be vol. xvi., has been finished after a year's concluding work upon it. Application has therefore been made to Her Majesty's Government for leave to print it, and official correspondence on the subject is progressing.

The astronomer has also contributed a rather exhaustive paper on the finishing of the great reflecting equatorial of the Observatory to the Council of the Royal Society, Edinburgh; and they in their turn have had it read before a full meeting of the Society.

While waiting for the result of both that proceeding and the printing correspondence for vol. xvi., the Astronomer has been preparing a series of thirty-one chronological tables of Scottish mean meteorology, extending month by month from the year 1856 to 1887 inclusive; and is even beginning a still longer series to show the local excesses of individual stations in each month in single years throughout the mainland and islands of Scotland, by utilising the something like seventy millions of figures which have already passed through the Observatory in carrying out the Government's meteorological returns.

Yet the working power of the Observatory has in reality been kept up with the greatest difficulty through the year, by reason of the continued absence during almost the whole of that time, on repeated medical certificates of one of the only two assistants belonging to the Observatory, viz., the second assistant astronomer. The straits of the occasion, however, partly alleviated by the voluntary services of an excellent mathematical student of suitable temperament, who appeared at the right time, have served to exhibit, in still stronger light than before, the masterly aptitude of the first assistant astronomer, Mr. Thomas Heath, B.A., of T.C.D., in disposing of vast quantities of figure-work with method, precision, and dispatch; and he has the astronomer's warmest private thanks as well as public acknowledgments therefor.

Royal Observatory, Cape of Good Hope.

Observations with the transit-circle have been continued regularly throughout the year, the objects of observation being the Sun, *Mercury* and *Venus*, the stars on the list of the Cape Ten Year Catalogue for 1890, comet comparison stars, stars occulted by the Moon, stars employed in the latitude and longitude determinations of the Geodetic Survey, and stars employed in zones for determining the scale-value of the heliometer. The work accomplished has been as follows:—

Number of determinations of collimation	.	.	.	53
„ „ level	.	.	.	417
„ „ nadir	.	.	.	415
„ „ runs	.	.	.	413
„ „ flexure	.	.	.	53
Number of observations of the meridian mark	.	.	.	562
Number of observations of stars in R.A.	.	Direct.	Reflex.	
	.	5584	274	
„ „ „ N.P.D.	.	5098	270	
Observations of both limbs of the Sun in both elements	.	.	.	178
Observations of Mercury	.	.	.	112
„ Venus	.	.	.	145

During the winter period, April 1 to September 30, a large number of double transits of circumpolar stars have been secured, which complete the data for the formation of a new fundamental catalogue of southern circumpolars, which will soon be ready for press.

On account of the illness of Mr. Pett, who was charged with the employment of the Great Indian theodolite (an illness which necessitated his absence in England during the last six months of the year), the work with that instrument was much interrupted. The amount of work done has therefore been limited, viz. :—

- 61 Observations of azimuth of fundamental circumpolars at greatest elongation.
- 47 Observations of azimuth of other stars at greatest elongation.
- 77 Azimuths of pairs of N. stars for latitude (Kapteyn's method).
- 55 Observations of the azimuth marks.
- 13 Determinations of runs.

With the zenith telescope 365 pairs of stars have been observed in connection with the latitude (Kapteyn's method), and for control on the law of flexure of the transit-circle.

The general rule has been adhered to of observing all comets visible south of the Equator, or which otherwise cannot be favourably observed in the northern hemisphere.

- a* 1887 was observed on 6 nights between Jan. 22 and Jan. 28.
- f* 1886 „ 4 „ „ April 29 „ June 16.
- e* 1887 „ 12 „ „ May 19 „ June 17.

f 1886 was picked up by Mr. Finlay whilst sweeping for comets on April 29 in the early morning, and his observations are probably the only existing ones of that object after perihelion.

The following occultations of stars by the Moon have been observed:—

Disappearance at the bright limb	1
Reappearance at the bright limb	1
Disappearances at the dark limb	20
Reappearances at the dark limb	19
Total		41

The photographic *Durchmusterung* has been pushed forward as rapidly as possible. Recently a supply of Derby dry plates has been received, and these permit the exposure to be reduced to half-an-hour instead of one hour, as formerly. The work will henceforth proceed much more rapidly. During the year 387 perfectly successful plates have been taken in connection with the *Durchmusterung* besides 82 rejected plates, and 43 plates for the selection of comparison stars for heliometer observation and for various miscellaneous and experimental purposes.

All the plates from declination -90° to -57° have been transmitted to Professor J. C. Kapteyn; the zones to declination -46° are all but completed, and great progress has been made as far as declination -34° .

Professor Kapteyn has completed the measurement reduction and cataloguing of the stars from declination -90° to -78° . The following are the comparative number of stars in the zones of the southern *Durchmusterung*, compared with Argelander:—

	No. of Stars in Northern <i>Durchmusterung</i> .	No. of Stars in Southern <i>Durchmusterung</i> .
-80°	793	921
-81°	844	920
-82°	751	822
-83°	675	739
-84°	547	648
-85°	412	543
-86°	347	396
-87°	220	363
-88°	143	252
-89°	38	66
Totals . . .	4770	5670

Professor Kapteyn has secured additional pecuniary aid, partly from his Government and partly from scientific societies in Holland, and he is now making such rapid progress in the measurements and their reduction that he expects to complete the whole work within four years. The photographic work at the Cape will probably be completed within the next two years.

During the first six months of the year H.M. Astronomer was absent from the observatory for the purposes of inspecting the new heliometer (completed for the observatory by Messrs. Repsold in Hamburg), of attending the Astrophotographic Congress in Paris, and passing some observatory publications through the press.

The heliometer reached the observatory by the steamer in which Mr. Gill returned, and was erected and adjusted without accident or delay.

The instrument is now in perfect order and adjustment, and regular work has been commenced.

It is in every respect perfect, and is, without doubt, the most powerful and convenient instrument for refined micrometric research at present in existence.

A complete working programme has been prepared, including the determination of the parallax of all the southern stars brighter than magnitude 2.0, and all the stars most remarkable for proper motion.

The necessary comparison stars (in general two pairs at least for each star) have been selected; the epochs of parallax maxima and minima and other necessary preliminary computations have also been completed. Some progress has been made in the determination of the errors of division of the scale and screw, as well as in the scale-value and other constants of the instrument, and work on the parallax determination of a few of the stars has been commenced.

Some inconvenience was at first encountered by the inefficiency of ordinary batteries to charge the accumulators necessary for the supply of electric light; but this difficulty has been overcome—first, by use of a dynamo kindly lent by a firm in Cape Town, and since by the liberality of the Lords Commissioners of the Admiralty in sanctioning a proper dynamo and set of accumulators for the electric illumination of all the instruments of the observatory. The wires have been laid down, and Mr. W. H. Preece, F.R.S., has kindly superintended the construction of the new dynamo and accumulators, which will reach the Cape before the end of January.

The field work of the Geodetic Survey, mentioned in last year's report, has been completed by the execution of the triangulation from King William's Town to Port Elizabeth, by the telegraphic redetermination of the astronomical longitude of Port Elizabeth, and by final latitude and azimuth observations at the same station. Major Morris, R.E., is about to take up his quarters at the observatory, and the work of final reduction will be immediately undertaken.

The measured length of the base line at Port Elizabeth (mentioned in last report) differs from its length computed through about 500 miles of triangulation from the Natal base by two inches.

The minute corrections (hardly reaching $0''.1$ in any case) applicable to the measured angles will be computed so as to equalise the computed and measured lengths of these bases.

The probable errors of the measured bases are in each case less than 0.05 inch.

The Cape Standard Ten-foot Bar A has been compared at the International Bureau of Weights and Measures at Paris, and an apparatus has been devised by H.M. Astronomer, and constructed by Messrs. Troughton & Simms, for determining the absolute constants of the measuring bars by comparison with the Standard Bar A.

Absence from the observatory, the erection and adjustment of the heliometer, together with the heavy pressure of a great variety of work requiring the close personal attention of H.M. Astronomer, have rendered it impossible for him to complete the reductions of the observations of *Victoria* and *Sappho* made in 1882, but it is expected that the work will be completed within the current year.

The following works were passed through the press by H.M. Astronomer during his visit to England:—

“Meridian Observations made at the Royal Observatory, Cape of Good Hope, during the years 1882, 1883, and 1884.”

“Occultations of Stars by the Moon observed at the Royal Observatory, Cape of Good Hope, in the years 1835 to 1880, compared with Hansen’s Tables of the Moon.” *Annals of the Cape Observatory*, vol. i. part 4.

“On the Variations of the Instrumental Adjustments of the Cape Transit Circle,” by W. H. Finlay, M.A., Chief Assistant. *Annals of the Cape Observatory*, vol. ii. part 2.

The meteorological observations made in the year 1886 at the observatory, together with those taken in different parts of the colony, have been printed in the “Report of the Cape Meteorological Commission.”

Armagh Observatory.

The micrometric observations of nebulae mentioned in previous reports have not made much progress during the past year, but the refractor was employed to examine a number of doubtful cases which presented themselves during the compilation of a new general catalogue of Nebulae. To the preparation and passing through the press of this work (which has just been published in the *Society’s Memoirs*) the Astronomer has had to devote almost his whole time.

Cambridge Observatory.

In carrying out the plan of observing each of the stars in our zone, if possible, at least three times, 2,047 observations have been made with the meridian-circle for the determination of Right Ascension and North Polar Distance. Of these 719 were observations of standard stars for clock correction; and 74 observations of *Polaris* above pole, involving 178 circle readings, and 66 below pole, involving 140 circle readings, were made for instrumental correction; 67 were observations of stars compared with *Sappho*; and the remaining 1,121 were observations of zone stars. Some of the zone stars in the observing list are so faint that they can only be taken on very clear nights, and few such have occurred during the year. Clock stars have been observed on 149 nights, of which only 93 were found to be suitable for the observation of zone stars, and few out of the 93 were clear enough for the very faint ones.

The Zenith Point, the Level Error, and the Error of Collimation have each been determined 227 times.

As regards the reductions and formation of the catalogue:—The true North Polar Distance of all the stars is calculated up to October 15, 1887, and the true Right Ascension to the end of July 1887. For the standard stars, the mean co-ordinates for the beginning of the year are obtained up to the end of 1886; for the zone stars to the end of 1883. The zone stars are reduced to the epoch in North Polar Distance up to August 1880, and in Right Ascension up to March 1880.

For the formation of the catalogue of zone stars, the Mean places for the epoch, 1875, are collected to the end of 1878, from 0^h to 5^h Right Ascension.

As in previous years, we have been called on several times for places of stars with which other heavenly bodies had been compared.

On June 30 places of four zone stars were furnished to Dr. Holetschek of Vienna. One had been observed by us four times, one three times, one twice, and one once. Another which he required, being smaller than the 9th magnitude, and having no letter annexed to it in Argelander, did not come within the scope of our zone work, but it will be observed when the proper time of year comes round.

On July 13 Mr. Bryant was furnished with places of seventeen stars which had been compared with the planet *Sappho*, deduced from sixty-four observations with the transit-circle; and also with seven places of *Sappho*, obtained from comparisons with ten of these stars in January and February 1887, by means of the Northumberland equatorial and square bar micrometer.

Mons. C. F. Pechüle, of the Copenhagen Observatory, asked for the places of forty-three stars. Thirty-six of these, deduced

from ninety-eight observations, were forwarded to him on September 21; the others, which do not strictly lie within the limits of our zone, will be observed in due course.

Dunsink Observatory.

Since the date of last year's report the observation of stars known or suspected to have a large proper motion has been continued. During the year a number of stars has been added to the working list, which at first did not contain a great many, having been compiled almost exclusively from the sources mentioned in our report for 1886. Early in the year, however, all the stars given by Dr. Dreyer in the *Monthly Notices* for May 1886 were included, as well as all the stars in the *B.A.C.*, which are there credited with a proper motion greater than $0''.2$ annually. Although many of these proper motions rest on the slenderest foundation, it was thought better to include them in the list for the sake of uniformity, as having been at one time suspected of a motion greater than that amount which was the limit decided upon when commencing the list. These, with a few stars which have been from time to time found in the *Astronomische Nachrichten*, have raised the number on the working list to nearly a thousand.

The meridian-circle and chronograph have, throughout the greater part of the year, been devoted to observations of these stars. There have been 1,028 meridian observations, of which 524 were observations of R.A. and 504 of Declination. The collimation error has been determined 150 times, the level error 83 times, the nadir point 173 times, and the error of run of the microscope 47 times. There have been 193 observations of the R.A. of standard stars for the determination of clock and azimuth errors, and 65 of Declination to serve as a check on the reading of the nadir point.

In November a series of observations was commenced of the zenith distance of *Polaris*, direct and reflected, at both culminations and in both positions of the instrument for the determination of the latitude. By the end of the year 92 such observations had been taken. A number of measures were also made of two spaces, one on each circle, which are employed for determining the error of run, as it was suspected that the sudden change which always occurred in this quantity on the reversal of the instrument was due to an error in the assumed length of one of them. These observations showed that one of these spaces corresponding to $2'$ on the circle (the arc $45^\circ 0'$ to $45^\circ 2'$ on Circle B) was $0''.67$ less than the value given for it in Part IV. of the *Dunsink Observations*.

The reductions of the meridian observations, which at the

beginning of the year had fallen very much into arrears, are now in a forward condition. The Right Ascensions up to the end of the year have been all reduced, and the Declinations with but a few exceptions. All the stars of the new working list observed from September 1885 till July 1887 have been reduced to mean place during the year.

In addition, the sheets of Part VI. of the *Dunsink Observations*, which will contain the places of the southern stars mentioned in former reports, have been printed, and are now in the binders' hands.*

During the night of October 12 the South equatorial was employed in observing the occultation of *Regulus* by the Moon, an account of which has been already published in the *Monthly Notices*.

Glasgow Observatory.

The operations at the Glasgow Observatory during the past year have been confined mainly to observations with the Transit Circle of a list of stars in the earlier volume of Weisse's Bessel, the mean places of which were found not to agree sufficiently well with the mean places of the same stars in the Glasgow Star Catalogue. The observations are now drawing to a close, and it is to be hoped that the results will serve to clear up the question whether the discordances are attributable to proper motion or to some other causes.

The total eclipse of the Moon of January 28, 1888, was observed under favourable circumstances. Fourteen star observations (six disappearances and eight re-appearances) were obtained in connection with M. Döllén's method for correcting the apparent diameter and parallax of the Moon.

The Kew Observatory of the Royal Society, Richmond, Surrey.

The sketches of Sun-spots, as seen projected on the photo-heliograph screen, have been made on 180 days, in order to continue Schwabe's enumeration, the results being published in an Appendix to the Annual Report presented to the Royal Society.

Three hundred and forty-seven observations of solar and 80 of sidereal transits have been taken for the purpose of keeping correct local time at the Observatory, and the clocks and chronometers have also been compared daily.

The following clocks: French, Shelton K. O., Shelton 35, and

* Since this report was written, Part VI. of the *Dunsink Observations* has been issued.

the chronometers: Molyneux, No. 2125, Breguet, No. 3140, and Arnold 86, are kept carefully rated as timekeepers at the Observatory.

The mean-time clock, Dent 2011, has been bolted to the wall of the chronometer-room for use in daily comparisons with the chronometers on trial.

The library of the Observatory has received a present from Wm. J. Davis, Esq., of a MS. volume of Sun-spot observations made at Edmonton, Middlesex, from August 1819 to March 1823. It is intended to enumerate the spots after the Schwabe method, so as to carry the Observatory catalogue of the new groups of Sun-spots back to 1819.

At the request of the Chairman, the MSS. Sun-spot measurements and reductions from February 1862 to December 1863, together with the tables for computing the spotted positions, as well as the Kew working catalogues from 1864 to 1872, have been forwarded to Mr. A. L. Soper for the purpose of further discussion.

The Indian Pendulum Apparatus was put up in the room specially erected for its accommodation in the South Hall of the Observatory, and certain preliminary swings made in the presence of both General Walker and Colonel Heaviside, R.E., which sufficed to show that the apparatus had not undergone any material changes since it left Kew in 1881.

It was, however, found that the vacuum chamber had received such structural damage in transit as to render it incapable of exhaustion to a sufficiently high degree to make the observations comparable with those previously made by Captains Basevi and Heaviside. It was accordingly returned to the maker, Mr. Adie, of London, for thorough repair, and has recently been again erected in its place, and found in a very satisfactory condition, so that the required preliminary observations may now be re-commenced.

By the kindness of Mr. W. H. Preece, F.R.S., the Committee were favoured with the loan of a recording chronograph for use in registering the coincidences. Experience proved that it was unnecessary, and the apparatus has since been returned to the General Post Office.

At the suggestion of Colonel Heaviside, photographs of the invariable pendulums were obtained on their removal from their cases after travelling, in order that a memorandum might be preserved of their figure and shape on their return to the Kew Observatory.

The arrangements for rating watches mentioned in previous reports have been carried on during the year with continued success, and up to the present 1344 watches have been examined and reported upon.

Five hundred and ten entries of watches were made, as contrasted with 490 during the corresponding period of last year,

and it is also extremely satisfactory to note that a very marked increase has taken place in the number of watches which have gained more than 80 marks.

Since the institution of chronometer trials, as mentioned in last year's report, 27 movements have been examined, and certificates issued giving the mean daily rate and variation of rate at each change of temperature.

A Kullberg's temperature regulator has been fitted by the maker to the chronometer oven, and a Richard thermograph is also arranged to work in the case with the chronometers, affording a continuous record of the temperatures which they have experienced during the whole of their trial.

The range of temperature from 55° to 85° F., to which the marine chronometers are submitted, has been decided upon after consideration, as being amply sufficient for determining the behaviour of chronometers under conditions to which they are usually exposed at sea, and no serious objections have yet been received from makers or others to the adoption of the above range.

By the kindness of the Astronomer Royal the Kew Observatory has been favoured with descriptions of the tests applied to Navy telescopes supplied by contractors to H.M. Service, and also descriptions of the apparatus employed at the Royal Observatory, Greenwich, for applying them.

A standard telescope of the Admiralty pattern has been purchased, and the necessary appliances are now being constructed, with the view of enabling the Committee to apply similar tests to telescopes submitted to them for verification by opticians and others.

An addition has also been made to the number of angle-measuring instruments verified, in the shape of range-finders. Several patterns of these instruments, for use both at sea and on shore, have been tested; two additional movable adjustable collimators with scales have been fitted to the sextant testing apparatus, to enable it to be used for the necessary purpose.

The magnetical and meteorological observations and reductions, and also the verifications of instruments, operations to which the attention of the Observatory is more particularly directed, have been still carried on as in former years.

Liverpool Observatory, Bidston, Birkenhead.

The Greenwich mean time, as deduced from observations of stars with the transit instrument, has been communicated to the port daily, Sundays excepted, by the firing of the time-gun placed on the pier-head of the Morpeth dock. No instance in

which the gun has failed to fire has occurred during the past year, and the flash has in each case accurately indicated 1^h P.M., as shown by the clock in the chronometer-room. Daily comparisons of clocks and chronometers have been made as heretofore. All chronometers deposited at the Observatory for the purpose of being tested have had their thermal errors determined by the systematic and symmetrically arranged test, in three definite and equidistant temperatures, devised by the late director of this Observatory. The delicate gas-governor invented by the late Mr. Alfred King enables the required temperature to be maintained within about one degree of Fahrenheit. The officers of the Pacific Steam Navigation Company have been supplied with the probable rates of their chronometers for the ensuing voyage, in each five degrees of temperature from 45° to 95° Fahr., and the records received of the performance of the instruments show the accuracy with which Greenwich time can be carried on at sea under such conditions.

The meteorological work has been conducted as in previous years. No interruption has occurred in the records of the self-registering instruments.

Radcliffe Observatory, Oxford.

The following have been the subjects of observation during the year 1887:—

With the transit circle:—

1. Observations of stars to the seventh magnitude inclusive between 115° N.P.D. and the equator.
2. Observations of the Moon, which are continued throughout the lunation, and regularly compared with the Right Ascensions and North Polar Distances of Hansen's Lunar Tables. Such comparisons appear to have a special value in keeping distinctly before astronomers the extraordinary character of the change between the results of observation and theory which took place about the year 1864. The mean error in longitude of Hansen's Tables has changed from $-1''.61$ in the year 1863.5 to $+15''.65$ in the year 1887.5, being at the average of $0''.72$ per annum.
3. Observations of the Sun.
4. Reflexion observations of stars.

The following table gives the number of observations made during the year 1887:—

Transits, 2,820.

Circle observations, 2,290.

These totals include—

- Observations of the Moon on 49 days.
- Observations of the Sun on 59 days.
- 19 Reflexion observations of stars.
- 171 Determinations of Nadir point.
- 1 Duration of passage of the Moon's diameter.
- 6 Vertical diameters of the Moon.

With the extra-meridional instruments :—

- 13 observations of 8 occultations of stars by the Moon.

The Barclay Equatorial has been mounted and brought into regular use. The values of the scales of the micrometers have been determined; and the instrument has been employed in the measurement of double stars, observations of Comet 1887 *e* (Barnard, May 12), and some star-charting.

The volume for 1884 has been printed and distributed.

The volume for 1885 is being prepared for press.

The observations made in 1886 are completely reduced; the N.P.D. reductions for 1887 are complete; the R.A. observations, 1887, are all entered to date and partially reduced.

University Observatory, Oxford.

The work at this Observatory has proceeded steadily on the same lines as those recently adopted, and mentioned in the last report.

The parallax of μ *Cassiopeiae* has been computed. That of *Polaris* and of η *Cassiopeiae* will require continued observation until August next, owing to breaks in the continuity of the work caused by alteration and renovation in the De la Rue instrument. A plan is now in progress of execution for determining on one system the parallax of all stars of approximately the second magnitude suitably situated at Oxford. This applies to thirty stars, and may be expected to occupy three years. It has been found that little or no advantage in point of accuracy, and certainly no commensurate advantage, arises from continuing the photographs uninterruptedly throughout the year; in future they will be confined to those periods when the position of the star in the so-called parallactic ellipse shows the greatest and least displacement from each of the four stars of comparison employed.

Much time has been spent upon the examination of two mirrors each of fifteen inches aperture, and of eighty and one hundred and twenty inches focal length respectively, the main object being to ascertain what photographic effects or advantages are due to focal length. This inquiry is undertaken at the request of a Committee of the Royal Society, to whom a report will

in due course be presented. Owing to abnormally unfavourable skies and some defective mechanism, the inquiry has proved very troublesome, but the difficulties, it is now believed, are overcome.

Dr. De la Rue has generously placed a considerable sum of money at the disposal of the Board of Visitors for the provision of a Photographic Telescope, suitable for carrying on the charting work of the heavens, proposed at the recent Paris Conference. The preparations are in the hands of Sir H. Grubb, who, at length, has obtained the discs of glass necessary for the purpose, and the instrument will be completed without delay.

The University has acknowledged Dr. De la Rue's munificence by a formal vote of thanks in Convocation, and has provided the means of carrying on the above photographic work for the next five years. In the vote of thanks, Mr. Barclay and Mr. Nasmyth have been included; the former for the gift of his admirable Transit-Circle, and the latter for his superb Cartoons of Lunar Formations. These latter now utilise and adorn the walls of the Lecture Room of the Observatory, and have been advantageously employed as illustrations in some recent public lectures.

The work of the Observatory has been greatly aided by the ability and perseverance of the two assistants, Mr. Plummer and Mr. Jenkins.

Temple Observatory, Rugby.

During the year 1887 more use has been made of the Observatory by members of the School than in former years, chiefly in the practice of finding the errors of the transit and other instruments, and in correcting observations.

The Observatory has been open on 67 nights, during the greater number of which boys have been present.

The original work has been consequently less than in former years. Mr. Percy Smith has made measures of 50 double stars, and Mr. Seabroke has made 121 sets of measures on 44 different stars with the spectroscope for the detection of motion in the line of sight.

The usual routine work for the correction of clocks has been continued as before.

Stonyhurst College Observatory.

The meteorological, magnetic, and solar work have all been carried on as in preceding years. Solar drawings, $10\frac{1}{2}$ inches to the diameter, have been made on 259 days, spots and faculæ being drawn most accurately to scale; and the chromosphere

has been measured completely 123 times, and partially thrice. Great attention continues to be given to the general examination of the solar surface, and to the study of the different classes of veiled spots. On days on which the definition was exceptionally fine attempts were made to determine the direction of solar surface currents by observing the inclination of the chromosphere filaments and of the lesser prominences. Occasional observations were also made of spot spectra in the region between B and D.

The umbra and penumbra of all the spots of 1886 and 1887 have been measured, expressed in millionths of the visible solar hemisphere, and reduced to curves.

Positions were obtained of Comets Finlay and Barnard; and the assistants of the observatory have taken part in a systematic watch for meteors. The phenomena of *Jupiter's* satellites, and occultations of stars by the Moon, were observed on most favourable occasions.

Several months of the year were principally devoted to collecting and adapting the instruments, and in making photographic experiments, in preparation for the total solar eclipse of August 19, and in the journey to Russia. The chief addition to the instruments of the Observatory was a large heliostat made by Hilger for spectroscopic work.

Mr. Common's Observatory, Ealing.

Considerable progress has been made in the construction of the 5-ft. reflector. The mirror has been polished and figured several times in order to gain experience in the art. There is evidence of internal strain in the glass, which may or may not affect the image, and it is contemplated to order another disc in case this one does not permit of a good final figure.

The mounting is in a forward state, the telescope tube being connected to the polar axis, this latter being a wrought-iron cylinder about eight feet diameter which will float in a tank of water, so as to relieve the friction in the manner mentioned in vol. xlv. of the *Monthly Notices*, p. 367.

The house or covering for the telescope, which will also carry the platform for the observer when the telescope is used as a Newtonian, is framed together and partly erected. It is hoped that the whole will be ready to use in the autumn.

MM. Henry have most kindly just placed at Mr. Common's disposal a fine plane mirror suitable for the telescope when used as a Newtonian.

The Earl of Crawford's Observatory, Dunecht.

During the first and last quarters of the past year the Transit Circle has again been used by Dr. L. Becker on moonlight nights for the observation of comparison stars, and stars within one degree of the pole, while in the absence of the Moon places of the brighter nebulae have been determined. The latter work has been much facilitated by the introduction of a new frame carrying only seven right ascension wires. The temperature of the transit-room has, with great advantage, been brought nearly down to that of the outer air by enclosing the gas lamps and their long ventilating tubes in roomy casings of bright tin-plate.

Early in the spring plans were worked out for establishing a large spectroscope on the top of a commanding hill, the Barmekin of Echt, about a mile and a half W.S.W. of the Observatory, with a view to laying down the low-sun lines. In the month of May two portable huts were erected on the crown of the hill, in one of which the large Rowland grating was mounted with a collimator and viewing telescope of four inches aperture. As might have been expected, the spectrum, when the sun was near the horizon, showed an immense number of atmospheric lines, especially on the rare occasions when a sufficiently narrow slit could be used at altitudes of less than one degree. As it was necessary to note down both the appearance and position of these lines as quickly as possible, a recording apparatus was brought into use which had been devised in the course of the preceding winter. By its help as many as 540 lines have been recorded in position and thickness in less than an hour. As the interval between sunset and sunrise at midsummer is only six hours, and as it was necessary to identify forthwith the chief lines in each set of observations, complete camping accommodation was provided at the station. So well did this arrangement work, that Dr. Becker, favoured by the unusually fine summer, by remaining on the hill every night succeeded in recording no fewer than forty-eight sunsets or sunrises in the months of June and July. The observations are the more valuable, as about the beginning of August heavy rains set in, and the weather in general was so unfavourable that only two sunrises, and not a single sunset, were observable in that month. Nor did the skies improve much before the end of the year, for in the last ten weeks there were but five nights on which nebulae could be observed in the meridian, while the fifteen first weeks of the year yielded seventeen nights suitable for that class of work. As at present arranged, the low-sun apparatus can only be conveniently used when the sun is north of the equator, but eventually it is hoped that some typical parts of the spectrum can be observed in the middle of winter. Last year's work was intentionally kept almost entirely between wave-lengths 516.5 and 604^{mm}.

Within these limits upwards of 13,000 observations have been made, and for them the normal lines are all reduced. 4,500 records of lines have been reduced to the final wave-lengths on the basis of Prof. H. A. Rowland's paper "On the Relative Wave-length of the Lines of the Solar Spectrum," in the *Amer. Journ.* for March 1887.

The large Cooke spectroscope was used by Dr. Copeland on the 15-inch equatorial on twenty-one nights in January to March for measuring the spectra of stars and nebulae. With it the temperature coefficients of three prisms were also deduced from a long series of readings taken at various temperatures, partly in a heated room. In December a few observations were made with the Grubb stellar spectroscope.

In the course of the year twenty-one circulars were sent out, almost exclusively about comets. As in former years, Dr. Oppenheim, of Berlin, supplied a large part of the computations, and to him the thanks of observers are due.

Very much time has been devoted to the library in checking and revising the titles and descriptions of the books. In May the printing of the catalogue was commenced. About one-third of the work has been passed through the press.

Particulars of Dr. Copeland's journey to Russia for the purpose of observing the total eclipse of the Sun are to be found on p. 48 of this volume.

The weekly firing of the time-gun and the daily meteorological observations have been continued as in former years.

Mr. Crossley's Observatory, Bermerside, Halifax.

As usual at this Observatory, the phenomena of *Jupiter's* and *Saturn's* satellites, occultations of stars by the Moon and transits of stars for time, have been observed whenever the weather and the demands on time made by the reflector permitted. About thirty of the phenomena of *Saturn's* satellites have been observed.

Much time has been devoted to the improvement and adjustment of the equatorial movements of the 3-foot reflector, the completion of the dome, the testing of the large mirrors and flats, the mounting and support of the flats, the art of silvering mirrors, and the mechanical means of handling them with safety, &c.

The A mirror was resilvered in December, and is now in the telescope. It is intended shortly to give a full description of the Observatory and some account in detail of the above work.

Mr. Huggins's Observatory.

During the last year the principal instruments have undergone careful cleaning and repairs. The lenses of the 15" achro-

R 2

matic object-glass, which have remained united with castor oil since 1870, have been separated, cleaned, and again put together with castor oil.

The driving clock has been cleaned, and the driving screw has been recut.

New spectroscopes and other apparatus have been added to the appliances to be used connected with the refractor and the reflector, which are mounted on the same equatorial stand.

These improvements, which have occupied many months, have prevented new work being done beyond the observations necessary for the adjustments of the different instruments.

Mr. C. E. Peek's Observatory, Lyme Regis.

Astronomical observations have been continued during 1887. No repairs or alterations of the building have been required, and the machinery for working the dome and transit shutters remains in perfect order.

One hundred and sixty-five nights were available. The most cloudy month was January, and the clearest August. The year 1887 was therefore more favourable to astronomical work than 1886, in the proportion of 165 to 146 observing nights.

Transit observations for time were taken on all available nights, and both sidereal and mean time chronometers have preserved satisfactory rates.

The mean-time service has been considerably improved by laying a wire and sending an hourly signal from the Standard clock to a Turret clock, which gives G.M.T. to the district.

The subjoined table gives the long-period variable stars under regular observation with the equatorial telescope of $6\frac{4}{10}$ inches aperture, and the number of nights on which each has been observed during the year:—

Star's Name.	Observations.	Star's Name.	Observations.
S Cassiopeæ	18	R Böötis	16
R Piscium	8	S Coronæ	16
R Tauri	6	R Serpentis	13
R Orionis	3	S Herculis	15
T Orionis	19	R Aquilæ	13
R Geminorum	5	R Cygni	15
R Cancri	6	χ^2 Cygni	16
V Cancri	13	S Cephei	17
T Ursæ Majoris	19	R Pegasi	13
S Ursæ Majoris	24	R Cassiopeæ	19

Several of these stars have been under observation since March 1886. The observations are all plotted on a uniform

scale, and as soon as any star has been observed over several complete periods it is proposed to publish a memoir with plates showing the variations in the light curve.

Colonel Tomline's Observatory, Orwell Park, Ipswich.

The work of this Observatory has been confined to the continuous observation of comets. Seven of these bodies in all have been observed during the year, but two of them belong more properly to the previous twelve months. The following table will give most conveniently a summary of this work:—

Name of Comet.	No. of times observed.	Between what dates observed.
Barnard-Hartwig	3 (part of a series of 24 observations)	Jan. 2—Jan. 10
Finlay	5 (part of a series of 20 observations)	Jan. 12—Feb. 25
Brooks	32	Feb. 12—Apr. 23
Barnard I.	9	Feb. 13—May 20
Barnard II.	9	Feb. 28—Apr. 10
Barnard III.	20	June 9—July 28
Olbers	21	Sept. 12—Dec. 27

Further observations of the last of these are yet hoped for. The reductions have been entirely effected, and the results (those of Olbers's comet excepted) have been communicated to the Society, and published in the *Monthly Notices*, vol. xlviii., No. 1.

As this department of astronomical study is only intermittently taken up elsewhere in England, it will be the aim of this Observatory in future to make the observations as full as possible and to include all comets visible in the northern hemisphere.

Lieutenant-Colonel Tupman's Observatory at Harrow.

The work of determining the places of comparison stars and other selected small stars has been continued with the meridian circle. Observations were made on eighty-two nights, in all 1150 chronographic transits and 1040 observations of N.P.D., all four microscopes being twice read for each circle reading. These observations are completely reduced. The correction for runs has shown no sensible variation since the instrument was mounted. On each night a star was observed below pole for azimuth error, and the level error was determined twice by spirit

level. The collimation error was found on thirty-one days by reversing the instrument and observing the N. collimator, which, with its pillar, having been thickly covered with felt, is much steadier.

By means of the large number of fundamental stars observed, differing considerably in declination on the same night, a preliminary investigation has been made of the errors of division of the circle in terms of the system of declinations of the *Berliner Jahrbuch*, between the zenith and equator, the difference for this interval being $1''$.

A few stars passing very near the zenith were observed for co-latitude, the result being identical with that previously obtained.

The observing list for the meridian circle now contains all the comparison stars used by Mr. Plummer for his recent comet observations (*Monthly Notices*, vol. xlviii. No. 1), many of Mr. Bryant's in connection with *Sappho* and two or three hundred other stars.

The Equatorial comparisons of comets, &c. have all been published in the *Monthly Notices*.